UNIVERSITAS BERGENSIS

DET PSYKOLOGISKE FAKULTET

Ψ

Cognitive Activity in Insomnia

HOVEDOPPGAVE

Profesjonsstudiet i psykologi

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Høst 2002

Forord

Takk til Inger Hilde Nordhus og Ståle Pallesen som har vært veiledere for denne oppgaven. De har begge vært svært imøtekommende og tilstede, og det har vært lærerikt å jobbe sammen med dem. Hovedoppgaven har utviklet seg via misforståelser til økt forståelse, både når det gjelder temaet og de statistiske metodene som har blitt brukt. I denne prosessen har begge to stilt opp både i forhold til de konkrete problemene i oppgaven, og som støttende medspillere.

Den som sover synder ikke…

-men hva gjør den som
ikke sover?

Contents

Abstract

The study investigated the causal relationship between worry and insomnia. A 2 x 2 design (Worry x Induced sleeplessness) with repeated measures was employed. In all 96 female undergraduate students who scored high or low on a measure of worry (Penn State Worry Questionnaire) completed the study. The induced sleeplessness variable consisted of two levels defined by a double-blind distribution of 300 mg caffeine and placebo. The repeated measures were nocturnal cognitive activity, as measured by the Night-Time Thoughts Questionnaire, and sleep parameters derived from a sleep diary and an actigraph. The data were obtained from two consecutive nights. Worry was found to be associated with nocturnal cognitive activity on both nights and with subjective sleep parameters on the first night. The findings indicate that nocturnal cognitive activity occurs as an epiphenomenon of wakefulness. The results are discussed in terms of their relationship to various categories of cognitive activity and models of insomnia. A core implication of the findings is that cognitive activity caused by induced sleeplessness may be conceived of as rumination. There is a need for the development of an instrument that can distinguish between types of nighttime rumination, under which worry is one subgroup.

Sammendrag

Studien undersøkte årsakssammenhenger mellom bekymring og søvnløshet. Det ble brukt et 2 x 2 design (Bekymring x Indusert søvnløshet) med repeterte målinger. I alt fullførte 96 kvinnelige lavere grads studenter som skåret høyt eller lavt på et mål for bekymring (Penn State Worry Questionnaire) studien. Indusert søvnløshet hadde to nivåer. Disse var 300 mg koffein og placebo som ble distribuert i en dobbelblind prosedyre. De repeterte målene var nattlig kognitiv aktivitet, målt med et spørreskjema om nattlige tanker (Night-Time Thoughts Questionnaire), og subjektive og objektive søvnmål, målt med søvndagbok og aktigraf. Dataene ble samlet inn fra to påfølgende netter. Resultatene viser at det er en sammenheng mellom grad av bekymring og grad av nattlig kognitiv aktivitet på begge nettene, og mellom grad av bekymring og skåren på de subjektive søvnparametrene på den første natten. Nattlige tanker forekommer som et epifenomen av våkenhet. Resultatene diskuteres i forhold til modeller for søvnløshet og i forhold til hvordan kognitiv aktivitet forårsaket av søvnløshet kan kategoriseres. En sentral konklusjon fra studien er at tankene som oppstod kan karakteriseres som grubling (”rumination”). Det er et behov for å utvikle måleinstrumenter som kan skille mellom former for nattlig grubling, hvorav bekymring er en type.

COGNITIVE ACTIVITY IN INSOMNIA

Introduction

Sleep manifests itself as a cyclical, usually rhythmical, psychophysiological state with reduced physical and mental activity (Nielsen, Nordhus, & Kvale, 1998). Based on polysomnographic (PSG) recordings, sleep can be divided into five stages. PSG consists of electroencephalography (EEG) that records electric activity in the brain, electroocculography (EOG) that records eye movements, and electromyography (EMG) that records electric activity in the muscles (Rechtschaffen & Kales, 1968). Four of the stages are named by numbers, stage 1- 4, whereas the fifth is called Rapid Eye Movement (REM) sleep. Stage 1 – 4 is also called Non-REM (NREM) sleep because of the lack of REM in these stages. Stage 1 and 2 are characterized as light sleep based on the presence of low voltage waves in the EEG, while stage 3 and 4 are characterized as deep sleep based on the presence of short waves (also called delta waves) in the EEG (Rechtschaffen & Kales, 1968). The stages alternate throughout the night. Sleep begins with the NREM stages and proceeds to REM sleep. A night with normal sleep consists of several sleep cycles each containing NREM and REM sleep. Generally sleep is deeper in the first half of the night (Pallesen, 2002). It has been reported that the average sleep duration for adults with no sleep complaints is between 7 and 8.5 hours per night (Kripke, Simons, Garfinkel, & Hammond, 1979). There are individual differences regarding how much sleep that is needed to feel rested and function well the following day (Morin, 1993). A sleep disorder exists when the inability to sleep impairs the daytime functioning (Atkinson, Atkinson, Smith, Bem, & Nolen-Hoeksema, 1996).

Insomnia has been reported to be the most commonly presented sleep disorder (Bixler, Kales, Soldatos, Kales, & Healey, 1979). According to the International Classification of Diseases-10 (ICD-10; World Health Organization, 1992), insomnia is a condition with unsatisfactory sleep quantity or sleep quality that lasts for a longer period. The Diagnostic and Statistical Manual-IV (DSM-IV; American Psychiatric Association, 1994) defines insomnia as a complaint lasting for at least one month of difficulty initiating and/or maintaining sleep, or nonrestorative sleep. Insomnia is recognized as a widespread and persistent health problem that profoundly affects mood, efficiency, and social relationships (Lacks & Morin, 1992). Morin (1993) estimated it to be the second most frequent psychological disorder. Pallesen, Nordhus, Nielsen et al. (2001) reported that the prevalence rate of insomnia in the Norwegian population is 11.7%. However, the overall prevalence of insomnia reported in different studies varies widely, from about two to 48% (Pallesen, Nordhus, Nielsen et al., 2001). The criteria for a diagnosis of insomnia differ across different classification systems, thus making comparisons of prevalence rates across studies difficult (Harvey, 2001).

A distinction that is frequently being made is between primary and secondary insomnia (Espie, 1991). Primary insomnia refers to those instances in which insomnia is the only or major presenting complaint (Trinder, 1988). The label secondary insomnia is in general given when insomnia is not the basic or core problem, but has medical, psychiatric or substance etiology (Espie, 1991). In other words, insomnia is a symptom that accompanies several psychiatric and medical/somatic disorders, as well as being considered a disorder in itself. The distinction between primary and secondary insomnia implies that in some cases a condition, for example depression, causes insomnia, and in other cases insomnia is the core problem which may cause other symptoms, like for example depression (Lustberg & Reynolds, 2000). Consequently, the distinction represents a question of cause and effect, or whether insomnia is symptom or a separate diagnostic entity.

An association between insomnia and psychopathology has often been reported. In a literature review, Soldatos (1994) found psychopathology to be the second most powerful risk factor after female sex, for the occurrence of insomnia. However, the causative role of psychopathology could not be determined. In another litterateur review addressing the question of causality between general psychopathology and insomnia, Harvey (2001) concluded that there is evidence supporting the idea that insomnia do occur as a primary disorder as: (1) depression is predicted by the presence of prior insomnia (in that way depression becomes secondary to insomnia), (2) an effective intervention for the primary disorder does not alleviate the insomnia, and (3) insomnia is a risk factor for the development of psychological disorders. Espie (2002) has reached similar conclusions. In other words, in order to give somebody a diagnosis of primary insomnia, there is a need to differentiate it from other disorders that may present themselves as insomnia. There are for example some sleep disorders that may present themselves as insomnia, and it is necessary to eliminate these in order to give somebody a diagnosis of primary insomnia (Pallesen, Nordhus, Havik, & Nielsen, 2001; Morin, 1993).

Another distinction that is commonly being made is between objective and subjective insomnia. Subjective insomnia is a classification that is only valid when talking about primary insomnia. It denotes to complaints about poor sleep following objectively assessed adequate sleep, and it has also been called *pseudoinsomnia, experiential insomnia* and *sleep hypochondrias* (Trinder, 1988). Borkovec (1982) reported the prevalence rate of subjective insomnia to be just above 9%. Objective insomnia refers to complaints of poor sleep that corresponds to objective measures of sleep (Trinder, 1988). Examples of objective measures of sleep are actigraphy (activity-based monitoring), which has been found to be a useful tool to assess specific sleep disorders, such as for example insomnia (Sadeh, Hauri, Kripke, & Lavie, 1995), and PSG (Baker, Maloney, & Driver, 1999). Trinder (1988) argues, however, that subjective insomnia is a pseudodiagnostic classification which is flawed in that it demands objective measures to define it, and in that overestimation of time spent awake during the night is a common feature also for objective insomniacs. Still, the distinction is generally accepted as indicated in the International Classification of Sleep Disorders (ICSD; American Sleep Disorders Association, 1997), in which subjective insomnia is considered a subdiagnosis of insomnia called *sleep state misperception*.

Summing up then, insomnia may occur both as a primary and as a secondary disorder. As a primary disorder it is common to make a distinction between a subjective and an objective subtype. Primary insomnia is by definition not associated with other psychiatric disorders. However, it may still be influenced by a number of psychological factors, like for example cognition.

Cognitive activity in insomnia

Various psychological factors have been assumed to interfere with sleep, of which cognitive activity is a central one. Evidence supports the view that cognitive activity is associated with insomnia (Coyle & Watts, 1991; Kuisk, Bertelson, & Walsh, 1989; Nicassio, Mendlowitz, Fussell, & Petras, 1985).

Cognitive intrusions and presleep hyperarousal have been advanced as major causal factors in the origin and maintenance of sleep onset insomnia (Sanavio, 1988). Rachman (1981) defined unwanted intrusive thoughts as repetitive, unacceptable or unwanted thoughts, images or impulses that interrupt an ongoing activity, are attributed to an internal origin, and are difficult to control. In a study that addressed the question of what characterizes the presleep cognitive activity of insomniacs, it was found that the activity could be distinguished from that of good sleepers by being more focused on worries, problems and noises in the environment, and less focused on nothing in particular (Harvey, 2000). The same study reported that the insomnia group was more likely to think about not sleeping or about something that happened that day. In another study it was found that insomniacs reported fewer images than good sleepers, but that they had a higher percentage of unpleasant images compared to good sleepers (Nelson & Harvey, 2002). Further more, a positive correlation between sleep onset latency (SOL) and unpleasant images was found in the insomnia group (Nelson & Harvey, 2002).

Another line of research that supports the hypothesis that cognitive activity is a mediator of insomnia is the finding that cognitive behavioral therapy (CBT) has been shown to be effective in the treatment of insomnia (e.g. Morin, Blais, & Savard, 2002). In a study by Harvey, Inglis and Espie (2002) it was found that cognitive restructuring contributed significantly to a reduction in wakefulness.

In the following, various types of cognitive activity that has been suggested to interfere with sleep will be presented. Rumination, under which worry can be considered a subgroup (Martin & Tesser, 1996), is an example of unwanted intrusive thoughts, while dysfunctional cognition is characterized by faulty beliefs that are not necessarily intrusive.

Rumination. Martin and Tesser (1996) define rumination as “a class of conscious thoughts that revolves around a common theme and that recur in the absence of immediate environmental demands requiring the thoughts” (p. 7), whereas worry can be defined as “a chain of thoughts and images negatively affect laden and relatively uncontrollable: it represents an attempt to engage in mental problem solving on an issue whose outcome is uncertain but contains the possibility of one or more negative outcomes" (Borkovec, Robinson, Pruzinsky, & DePre, 1983, p. 10).

Martin and Tesser (1996) classify ruminative thoughts according to their valence (negative or positive), their temporal orientation (past, present, or future), and the focus of the thoughts (discrepancy focus or attainment focus). According to this classification system, worry is considered a subtype of rumination which has a negative valence and which is typically future-oriented. Worrying can both have a discrepancy focus as well as an attainment focus. The authors suggest that rumination is instigated by discrepancies in goal-progress and that these goals are hierarchically organized according to their importance to the person. Scott and McIntosh (1999) found three subtypes of rumination when using a factor analysis on a preliminary questionnaire for ruminative thought. The factors were *Emotionality*, which represents rumination about failed goal-attempts, *Distraction*, which represents the degree to which the subjects were distracted by the ruminative thoughts, and *Motivation*, which represents the degree to which the subjects were motivated to something to reduce their ruminative thinking. The Emotionality factor and the Distraction factor were found to correlate with two separate measures of worry, whereas the Motivation factor was not (Scott & McIntosh, 1999).

Worrying is a normal experience up to a certain point where it becomes pathological, and the concept is best described dimensionally along a continuum (Ruscio, Borkovec, & Ruscio, 2001). It has been suggested that worrying may function as a cognitive avoidance response to threatening information (Borkovec, 1994). An example of this would be coping preparations where worrying about a negative outcome gives the person a sense of internal control of the possible threats of the future (Borkovec, 1994). Further more it is assumed that the suppressing effects of worrying on autonomic activity are negatively reinforcing the worrying, and thereby an inhibition of emotional processing occurs. A study by Watts, Coyle, and East (1994) found worry to be correlated with insomnia. However, insomnia did occur without worrying, implying that worry was not a necessary feature of insomnia.

Dysfunctional cognition. Morin (1993) has argued that dysfunctional beliefs about sleep influences sleep. He states that dysfunctional sleep cognitions are of five types: 1) misconceptions of the causes of insomnia, 2) misattribution or amplifications of its consequences, 3) unrealistic sleep expectations, 4) diminished perceptions of control and predictability of sleep, and 5) faulty beliefs about sleep-promoting practices. Several studies have provided support for the view that dysfunctional beliefs are critical in determining sleep quality. In a study among 145 older adults examining the beliefs about sleep by using a questionnaire that measured personal beliefs and attitudes about sleep, it was found that insomniacs endorsed stronger dysfunctional beliefs and attitudes about sleep relative to self-defined good sleepers (Morin, Stone, Trinkle, Mercer, & Remsberg, 1993). Coyle and Watts (1991) found some cognitive factors to be particularly critical in determining the quality of sleep, and these were *Sleep attitudes,* which were concerned with performance anxiety about sleep, and *Mental activity,* which reflected cognitive activity of a nonspecific kind. Van Egeren, Haynes, Franzen, and Hamilton (1983) found that subjective insomniacs reported a greater proportion of presleep cognitions concerning negative sleep-related content, proprioceptive cues, and environmental cues. Morin et al. (2002) compared the treatment outcome of CBT, pharmacotherapy (PCT), a combination of CBT and PCT, and medication placebo in the treatment older adults with primary and chronic insomnia. The results showed that the CBT alone and the combination of CBT and PCT produced greater improvements on beliefs and attitudes about sleep at posttreatment than the PCT and the medication placebo did. Further more, a reduction in dysfunctional beliefs and attitudes about sleep was significantly correlated with an increase in sleep efficiency, as measured by a sleep dairy and PSG. The changes in cognition regarding sleep were more strongly associated with subjective than objective sleep parameters.

Cognitive activity in other disorders

The experience of having unwanted intrusive thoughts has been reported by both normal and clinical populations (Rachman & de Silva, 1978). Rumination, under which worry can be considered a subtype, has been reported to occur as a normal cognitive activity (Ruscio et al., 2001; Martin & Tesser, 1996) as well as an activity associated with abnormality (Ruscio et al., 2001; Nolen-Hoeksema, 1996). Considering that the distinction between insomnia as a primary or secondary diagnosis depends on what causes what, in addition to the hypothesized sleep-interfering effect of intrusive thoughts, it is meaningful to look at some common psychological diagnoses that share the symptom of intrusive thoughts. Intrusive thoughts are key features of several emotional disorders, such as obsessive-compulsive disorder (OCD), generalized anxiety disorder (GAD), and depression (Rachman, 1983).

GAD. Soldatos (1994) found that the percentage of insomniacs with various forms of anxiety disorders varies from 25 to 42%. Haynes, Follingstad, and McGowan (1974) found several correlations between anxiety measures and sleep patterns in insomniacs, and they interpreted this as a support for the hypothesis that arousal, or anxiety, is an etiological factor in insomnia. However, they point to inherent difficulties in delineating causal relationships. Lundh, Broman, and Hetta (1995) found that insomniacs scored high on *Psychic anxiety* (a subscale of the Karolinska Scales of Personality). The items concerned emotional sensitivity, slow recuperation after stress, and worrying. Morin and Ware (1996) states that almost all anxiety conditions except from simple phobias are associated with difficulties initiating and maintaining sleep,

Borkovec et al. 1983 have found that worry correlates with trait anxiety. Further more they report that worry, as defined by the time spent worrying during the day, correlates most highly is with social evaluative concerns (Borkovec et al., 1983). The worry found in GAD patients seems to be an excess of the same process that is found in non-anxious individuals (Borkovec, Shadick, & Hopkins, 1991). According to Borkovec (1994) the empirical literature indicates that the main differences between pathological and normal groups reside in the frequency, intensity, and uncontrollability of the phenomena.

OCD. Another diagnosis that is characterized by intrusive thoughts is OCD. Both worries and obsessions are recurrent, repetitive, and unwanted thoughts (Langlois, Freeston, & Ladouceur, 2000). Obsessions have been found to occur more often as images, and worries more often in verbal form (Langlois et al., 2000). In a study that compared the factor structure of worries and obsessive thoughts in a non-clinical population, it was found that worries are characterized by the intrusiveness of the thoughts and by the disturbance that they cause, while obsessions are characterized by the unpleasantness of the thought-content. The emotional charge was placed within the *Egodystonic* factor for obsessions and within the factor for

Perceived basis in reality for worries. The authors also report that *escape/avoidance* strategies were associated with the Egodystonic factor of the thought both for worries and obsessions. (Langlois et al., 2000). They conclude that obsessive thinking and worrying may share common processes, and that these may occur on a continuum. Clark and Purdon (1995) points out the importance of focusing on both content and process when assessing an intrusive thought to improve the discriminant validity of the measure for it. They state that the research in this field almost exclusively has focused on process.

Depression. Soldatos (1994) found that about 20% of insomniacs are also depressed, and that depression is more than twice as prevalent in depressed subjects as in non-depressed. However, the causal relationship could not be established from these studies.

When it comes to cognitive activity of depression, Beck (1970) operates with the concept of *negative automatic thoughts*. The thoughts are labeled as automatic because they are involuntary and seem to occur by themselves. They have a negative quality to them and are typically devaluating and about hopelessness (Beck, 1970). These characteristics are similar to worrying according to the definition presented earlier. The similarity to obsessive thoughts is less clear-cut. Salkovskis (1985) argues that negative automatic thoughts are different from unwanted obsessional intrusive thoughts in that they are less intrusive and more plausible, egosyntonic, rational, and difficult to access.

Rumination on sadness, as measured by the Rumination on Sadness Scale, has been reported to correlate with the Beck Depression Inventory (BDI; Conway, Csank, Holm, & Blake, 2000). Further it has been reported that instructing dysphoric people to ruminate leads to a worsening of mood, while instructing nondysphoric subjects to ruminate does not have this effect (Nolen-Hoeksema, 1996).

Regarding the relationship between worrying and depression, Davis and Montgomery (1997) states that it remains relatively unexplored. However, it has been found that a tendency to worry, as defined by the percentage of the day spent worrying, correlates significantly with the BDI (Borkovec, 1994).

Models of insomnia

Several models of the relationship between psychological factors and insomnia have been proposed. Three models will be presented here, and the focus will be on cognitive factors in relation to insomnia - especially on worrying.

Morin's integrative model. Morin (1993) has proposed that hyperarousal is the central mediating factor of insomnia. Hyperarousal can be manifested in verbal (cognitive-affective), motoric (behavioral), and physiological channels, and it may be caused by many factors, for example by internalizing of psychological conflicts. The model further states that the most common reaction to sleep loss is worrying and ruminating over the residual effects it may have, resulting in a tendency to try harder to fall asleep. The consequences of the sleep loss in various areas (for example socially or at work) will eventually result in learned helplessness in relation to the ability to fall asleep. In order to cope with the sleep loss, people engage in maladaptive habits that contribute to the maintenance of the problem. The model draws a picture of a vicious cycle that eventually may result in chronic insomnia. It also opens up for individual differences in how easily people get hyperaroused and worried, and thereby also the possibility that both trait and state factors are critical in the process of developing insomnia.

Espies psychobiological model. Espie (2002) proposes a model of sleep that assumes that sleep is a normal homeostatically driven process. Insomnia is proposed to be caused by an inhibition of the automatic dearousal processes that are necessary for normal sleep. According to Espie's (2002) model hyperarousal is a sufficient but not necessary component in the onset of insomnia, while according to Morin's (1993) model hyperarousal is both necessary and sufficient. Espie's (2002) model further more suggests that many factors can lead to an inhibition of sleep (situational, temporal, central, autonomic, cognitive, and affective) but that it is the cognitive or affective factor, like for example worrying, that gives rise to a complaint of insomnia. It is also implicit in the assumptions of the model that worry may be both a consequence and a reason to why the normal psychobiological sleeping requests are being inhibited. This is in line with Morin's (1993) model.

Lundh and Broman's model of sleep-interfering and sleep-interpreting processes. Lundh and Broman (2000) have proposed a model in which they argue that psychological vulnerability factors may predispose an individual to respond with sleep-interfering processes to stressful life-events, and to engage in dysfunctional sleep-interpreting processes. Among the personality characteristics that are hypothesized to predispose a person to engage in dysfunctional sleep-interpreting processes, perfectionistic standards with regard to sleep and daytime functioning is mentioned. Arousability, stimulus-arousal associations, and behavioral and cognitive strategies are also proposed as vulnerabilities for sleep-interpreting processes. Worry would be an example of an arousability factor, either as a trait factor or as a state factor. The authors state that perfectionistic concerns may influence sleep-interfering processes by contributing to vicious cycles of worries about sleeplessness, or by predisposing to stronger emotional responses in the face of negative life-events. High personal standards, dysfunctional beliefs, and attributions are suggested as vulnerability factors for sleep-interfering processes. It is also proposed that the relationship between sleep-interfering and sleep-interpretive processes is bidirectional in that arousal may produce more negative interpretation of sleep and sleeplessness, and these interpretations may further produce more arousal.

Summing up, intrusive thoughts, like for example worries, are believed to be a causal factor of insomnia. Several models that address the causal mechanisms of insomnia have been put forward. Common among them is the focus on cognitive mechanisms and on the transactional nature of insomnia and excessive cognition.

Hypotheses for the study

Several studies have found worry to be associated with insomnia (e.g., Ellis & Cropley, 2001; Watts et al., 1994; Gross & Borkovec, 1982). In one study addressing the question of what causes insomnia, it was found that when people suffering from insomnia were to determine what caused them not to sleep, most subjects perceived insomnia to be caused by cognitive arousal rather than somatic factors (Lichstein & Rosenthal, 1980). Still, the study does not address the question of causality, and the cognitive activity may both have occurred as a cause as well as a consequence of insomnia. In relation to this, it has been suggested that worrying might be an epiphenomenon of wakefulness (Borcovec, 1979), implying that worrying may by caused be nocturnal wakefulness. Presently the author of the manuscript at hand knows of only one study that has addressed the question of causality between worrying and sleeplessness experimentally. In the respective study it was found that telling subjects to give a speech after napping led to prolonged SOL (Gross & Borcovec, 1982).

In relation to the question of causality between insomnia and worry, several lines of evidence have found that subjective and objective sleep measures often differ. Wicklow and Espie (2000) found significant differences between actigraphic and subjective measures of sleep pattern, where the subjective measures overestimated the objective SOL with 100%. It has also been found that time-estimates increase proportionally with the amount of information that is being processed per time unit (Borkovec, 1982), especially when the information has negative valence (Van Egeren et al., 1983). It follows that the estimation of time may be exaggerated as a consequence of worrying.

One possible way to investigate the causal relationship between worry and insomnia would be to induce sleeplessness in people who tend to worry and in people who do not tend to worry, and at the same time measure the frequency of nightly worries and the value of various sleep parameters. To induce sleeplessness a stimulant agent, like caffeine, could be administered. The hypothesized delaying effect of caffeine on SOL has been supported empirically (Alford, Bhatti, Leigh, Jamieson, & Hindmarch, 1996; Bonnet & Arand, 1992).

In this thesis the question of causality between worry and insomnia is being addressed. Based on the literature elaborated above, the following hypotheses have been put forward: 1) Induced sleeplessness will lead to increases in frequency of nighttime worries, implying that worrying can arise as an epiphenomenon of sleeplessness; 2) Induced sleeplessness will primarily increase worrying in people who have a predisposition to worry; 3) Induced sleeplessness will result in larger SOL in subjects who tend to worry than in subjects who do not because of a possible transactional relationship between insomnia and worry; and 4) Subjects who tend to worry will have a larger discrepancy between subjective and objective sleep parameters than people who do not tend to worry since worrying is assumed to increase estimation of time.

Methods

Subjects

Ninety-six subjects participated in the study. The mean age of the total group was 21.2 years (*SD*=4.1, range=18-45). The participants were female students attending undergraduate courses. The rationale for recruiting females only was to secure equivalent groups since the Norwegian norms of the questionnaire that was used in the recruitment phase of the study, the Penn State Worry Questionnaire (PSWQ), have been found to differ significantly between female and male students (Pallesen, Nordhus, Thayer et al., 2001). The resulting two groups consisted of subjects who scored 55 or higher, the high worry (HW) group, and subjects who scored 42 or lower, the low worry (LW) group. The limits represent the upper and the lower cut-off scores that had been set at approximately a half standard deviation above and below the mean score of the PSWQ (*M*=48.3, *SD*=12.5) according to the Norwegian norms for females students (Pallesen, Nordhus, Thayer et al., 2001). In the present study a mean score on the PSWQ of 62.0 (*SD*=5.3, range=55-79) was reported in the HW group, and a mean score of 34.4 (*SD*=5.6, range=19-42) was reported in the LW group.

Design

The study was experimental and a 2 x 2 design with repeated measures was used (Worry x Induced sleeplessness). Two levels of worry were operationally defined in terms of LW and HW, and two levels of induced sleeplessness were operationally defined in terms of caffeine and placebo.

Apparatus and materials

PSWQ. The PSWQ is a 16-item self-report measure of pathological worry. Each item is rated on a 5-point scale, thus the total range of scores is between 16 and 80. PSWQ has shown sound psychometric properties (Meyer, Miller, Metzger, & Borkovec, 1990).

Scott-McIntosh Rumination Inventory (SMRI). SMRI is a self-report inventory measuring ruminative thoughts and it comprises 9 items, each of which is rated on a 7-point scale (Scott & McIntosh, 1999). It has got three subscales: *Motivation, Distraction* and *Emotionality*. The questionnaire was used on baseline to collect background information.

Sleep diary. A modified version of the sleep diary presented by Morin (1993) was used as a subjective measure of sleep. It consists of 16 items, and the following sleep parameters can be derived from the diary: SOL, wake-time after sleep onset (WASO), number of nocturnal awakenings, final wake-up time, total sleep time, sleep efficiency ([total sleep time/total time in bed], x 100), daytime alertness, morning alertness, memory for dreams, and evaluation of unpleasantness/pleasantness of dream content.

Actigraphy. As an objective measure of sleep actigraphy was used. An Actiwacht Plus unit (Cambridge Neurotechnology, 1999) is worn like a watch on the wrist, and it stores data about time and body movements. These data are later analyzed and scored according to specific algorithms, in order to be converted into sleep parameters. Actigraphy has been validated against PSG (Hauri & Wisbey, 1992) and sleep diary measures (Usui et al., 1999).

Night-Time Thoughts Questionnaire (NTTQ). To register nightly thoughts and worries the NTTQ, which is a 20-item questionnaire measuring the content of nighttime thoughts, was used. Every item is rated on a 5-point scale according to how much the subjects have thought about different matters during the night. The questionnaire has six subscales: *Mental activity and rehearsal, Thoughts about sleep, Family and long-term concerns, Positive concerns and plans, Somatic preoccupations,* and *Work and recent concerns* (Watts et al., 1994).

Sleep manipulation. 300 mg caffeine was administered to manipulate sleep. Placebo pills that looked identical to the caffeine pills were administered to control for the manipulation.

Procedures

The National Committee for Medical Research Ethics and Legemiddelverket approved of the study before the recruitment of subjects was initiated.

On the various lectures where the recruiting of subjects took place, all the students were asked to fill in the PSWQ, and to calculate their scores afterwards. They were given extra instructions on how to calculate reversed items. The females who fulfilled the inclusion criteria were invited to take part in a sleep experiment. Subjects who were pregnant or breastfeeding, or who were suffering from a heart disease, abdominal disease, or intestinal disease, were discouraged to participate. Those who showed an interest were first given an oral explanation of what would be asked from them. They were explained that participating in the experiment would involve filling in some questionnaires - some once and some twice, sleeping with an actigraph for two nights - one baseline night and one night for sleep manipulation, and taking three pills one hour before going to bed on the second night. They were informed that the pills would either contain caffeine or placebo, and that they might experience a poor night's sleep and/or some side-effects, like for example headache or nausea, after taking the pills. The subjects were told not to drink any alcohol on the two nights they were participating in the experiment, and not to complete the experiment during the weekend unless they had the same sleeping habits in the weekend as during the rest of the week. They were also told to go to bed as planned after taking the pills and to press a button on the actigraph when going to bed and when getting up in the morning (to register bedtime and getup time). Further more they were informed that the experiment was designed to explore if different people would respond differently to a poor night's sleep, and that there would be a 150 Norwegian crones compensation for participating. After the oral presentation the female students who wanted to participate in the study were asked to read and sign an informed consent. Eventually the participants were delivered all the material they needed in an envelope, and they were asked to complete the procedures during the following week. There was a written instruction of how to proceed in the envelope. The subjects were randomized into a placebo or a caffeine group by a double-blind procedure. The sleep diary, the actigraph and the NTTQ were used for the repeated measures, and the repeated measures were obtained for two nights, the baseline night and the experiment night.

A total of 116 female students were initially recruited to the study. Thirteen were excluded due to equipment missing, data missing, and dropout, thus leaving ninety-six subjects in the study. In the HW group 24 subjects received caffeine and 23 received placebo, while in the LW group 23 received caffeine and 26 received placebo. Eleven of the participants in the study had incomplete datasets. However, they were included in those analyses where the data were complete.

Statistics

Two-way ANOVA was used to calculate the effects of the manipulation on the repeated measures. To calculate differences on the repeated measures, the scores on the second night was subtracted from the first night resulting in difference variables. This was done for the separate items of the NTTQ, the subfactors of the NTTQ, the total score of the NTTQ, and for the sleep parameters measured by the sleep diary and the actigraph. One-way ANOVA was used to calculate the main effects of worry on the first night. t-test for independent samples was used to test for equality of means between the PSWQ and the SMRI. All significance tests were two-tailed and alpha levels of .05, .01, or .001 were used for all statistical tests. Pearson product-moment correlation was used to investigate the relationships between the score on the PSWQ and on the SMRI subscales, and it was used to estimate the correspondence between the subjective and objective sleep parameters. It was tested for significant differences between the HW and the LW group on the correspondence between the subjective and the objective sleep parameters by testing for whether the differences in correlation were significant.

Results

The HW group had significantly higher mean scores than the LW group on the PSWQ and the SMRI, and on the three subscales of the SMRI. (See Table 1.) The sum score of the PSWQ was found to correlate with the total score of the SMRI (r= ,54, p< .001), and with each of the three subscales of the SMRI (r=0.65, p<0.001; r=0.47, p<0.001; r=-0.33, p<0.001) for Emotionality, Distraction, and Motivation, respectively. (See Table 2.)

Caffeine was effective in inducing sleeplessness. This was represented in the finding that caffeine had a main effect on several of the sleep parameters. One main effect was found on sleep efficiency, which was significantly lower in the caffeine group than in the placebo group both according to both the objective and the subjective sleep parameters. Another main effect was found on WASO, which was significantly higher in the caffeine group than in the placebo group according to the actigraph. A last main effect was observed on SOL, which was found to be significantly higher in the caffeine group than the placebo group as measured by the sleep diary. (See Table 3 and 4.)

Caffeine, as compared to placebo, also had main effects on the difference scores from the first to the second night on several of the sleep parameters. One main effect was found on the difference score for sleep efficiency, which decreased significantly in the caffeine group both according to the sleep diary and the actigraph. Two other main effects of caffeine were observed on the difference scores of WASO and SOL. WASO increased significantly in the caffeine group according to the actigraph, while SOL increased significantly in the caffeine group according to the sleep diary. (See Table 3 and 4.)

A main effect of caffeine on the total score of the NTTQ was found, both on the second night score and on the difference score between the first and the second night. However, it was only found significant main effects of caffeine on the difference score between the first and the second night on three out of the six subfactors of the NTTQ. These were Mental activity and rehearsal, Thoughts about sleep, and Positive concerns and plans, and they increased from the first to the second night. Family and long-term concerns, Somatic preoccupations, and Work and recent concerns did not increase. (See Table 3 and 4.)

On the separate items of the NTTQ, caffeine was found to have a significant main effect on the difference scores of item number 2,3 5,7,13, and 14, as represented in an increase in score from the first to the second night on these items. The content of these items are *trivial things I don't need to think about, rehearsing unimportant things I will do tomorrow, wanting to sleep, not being able to sleep, important things,* and *long term-plans and projects*, respectively. (See Table 6 and 7.)

Worry had a main effect on sleep efficiency, SOL and WASO on the first night according to the sleep diary ($F(1,94)=14.32$, $p< .001$; $F(1,94)=7.42$, $p< .01$; $F(1,94)=4.37$, $p< .05$). The HW group had higher values than the LW group on these sleep parameters. The same main effects were not observed according to the actigraphic measures ($F(1,84)=0.07$, $p< .80$; $F(1,84)=0.05$, $p< .90$; $F(1,84)=0.05$, $p< .90$). No main effects of worry were found on any of the sleep parameters on the second night or on the difference scores from the first to the second night. (See Table 4.)

On the first night of the experiment, worry had a main effect on the NTTQ. The HW group was found to score higher than the LW group on the total score ($F(1,93)=53,92$, $p< .001$), and on Thoughts about sleep ($F(1,93)=24,49$, $p< .001$), Work and recent concerns ($F(1,94)=26,01$, $p< .001$), Somatic preoccupations ($F(1,94)=14,14$, $p< .001$), Mental activity and rehearsal $F(1,94)=11,31$, $p< .001$), Positive concerns and plans ($F(1,94)=16,25$, $p< .001$), and Family and long-term concerns ($F(1,94)=49,92$, $p< .001$). A main effect of worry on the total score and on all the subfactors of the NTTQ on the second night of the experiment was also found. (See Table 3.)

No main effects of worry were found on the difference score on Total nighttime thoughts from the first to the second night. The same was true for most of the subfactors of the NTTQ, with the exception of a main effect on the difference score on Concerns about family and long-term plans. This effect was due to an increase in the LW group and a decrease in the HW group from the first to the second night. (See Table 3 and 4.) When looking at the various items separately, a main effect of worry on the difference scores of item 8 and item 10 was found. The content of these items are *being tired tomorrow* and *concerns about family*, respectively. (See Table 5 and 6.) On both of these items, the effect was mainly represented as an increase in score in the LW group. (See Table 6 and 7.)

There were no significant interaction effects between worry and induced sleeplessness on the difference scores of the NTTQ. However, a non-significant trend of an interaction effect between worry and induced sleeplessness on Thoughts about sleep was found both on the second night score and on the difference score between the first and the second night ($p < .09$; $p < .08$). (See Table 2 and 3.) The trend was represented in that the effect of caffeine, as compared to placebo, on Thoughts about sleep was less present in the LW group than in the HW group. The trend was most present on item number 8, which is one out of the four items on Thoughts about sleep ($p < .09$; See Table 6 and 7). There were no significant interaction effects between worry and induced sleeplessness on SOL, or on any of the other sleep parameters. (See Table 3 and 4.)

None of the correlations between the sleep diary and the actigraph were found to differ significantly between the LW group and the HW group, neither on the first nor on the second night. However, it was found a significant difference in the correlation between the sleep diary and the actigraph on SOL on the second night between the LW and HW group among subjects who received placebo. The difference was represented in a high correlation in the LW group and a lack of correlation in the HW group. (See Table 5.) There was not found an equivalent difference between the LW and the HW group among subjects who received caffeine ($p > .05$; See Table 5.).

Thirty-seven percent of the subjects who received caffeine pills and 16 % of the subjects who received placebo pills reported side effects. Headache and nausea were reported most frequently.

Discussion

The PSWQ was found to correlate with the total score of the SMRI, and with each of the SMRI subscales. All the correlations were significant at an alpha level of .001. The correlations were positive with the Emotionality and the Distraction scale, and negative with the Motivation scale. The positive correlation between the PSWQ and the Emotionality scale indicates that people who score high on a measure of rumination about failed goal attempts, also score high on a measure of worrying. The same relationship was present in the correlation between PSWQ and the Distraction scale indicating that people who report getting distracted by their rumination also score high on a measure of worry. However, people who are motivated to do something about their rumination, score low on the PSWQ, as indicted in negative correlation between the Motivation factor and the PSWQ.

Caffeine, as compared to placebo, was found to be effective in inducing sleeplessness on the measures of sleep efficiency and SOL according to the sleep diary, and on the measures of sleep efficiency and WASO according to the actigraph.

Caffeine led to an overall increase in the frequency of nighttime thoughts. However, only three of the subscales of the NTTQ increased in score as a consequence of induced sleeplessness. These were Positive concerns and plans, Thoughts about sleep, and Mental activity and rehearsal. When analyzing the effects caffeine had on the separate items of the NTTQ, all the main effects were found on items that belonged to either Positive concerns and plans, Thoughts about sleep, or Mental activity and rehearsal. In other words, no main effects of caffeine were found on items that belonged to subfactors that did not increase. This finding strengthens the discriminant validity of the subfactors of the NTTQ (Watts et al., 1994). It also raises the possibility that inducing sleeplessness mainly causes an increase in limited areas of cognitive activity. Taken together, the manipulation was found to be effective in inducing sleeplessness, and the findings supported the hypothesis that nighttime worrying can occur as an epiphenomenon of wakefulness.

Worry was not found to cause an increase in nighttime thoughts in general from the first night to the second night. However, when looking at the difference measures of the separate factors of the NTTQ, a main effect of worry on Thoughts regarding family and long-term concerns was found. This effect was represented in an increase in the LW group, which is contrary to what would be expected (since increases on the NTTQ were predicted to occur in the HW group). However, the finding may represent a floor effect in the LW group since the score on the respective factor was very low on the first night. When analyzing the main effects of worry on the separate items of the NTTQ, it was found support for the hypothesis of a floor effect.

The two items that increased in the LW worry group (item 8 and item 10) were two out of the three items that had the lowest score on the first night in the LW group. The interpretation also seems worthwhile considering the finding that nighttime thoughts appear to be an epiphenomenon of wakefulness. Still, worried subjects had in general more nighttime thoughts than subjects who were not worried, as measured by the total score of the NTTQ on the first and on the second night of the experiment.

The hypothesis that induced sleeplessness would increase SOL relatively more in the HW group than in the LW group was not supported by the data. However, a trend that worry and induced sleeplessness interacted on one of the factors of the NTTQ, Thoughts about sleep, was observed. The finding was not significant. However, it seems of interest for further elaboration.

The correlations between the subjective and the objective measures of sleep were not found to differ on sleep efficiency, SOL, or WASO between the HW and the LW group on the whole. The finding implies that subjects who had a predisposition to worry did not report a larger discrepancy between subjective and objective sleep parameters than subjects without a predisposition to worry. In other words, estimation of time did not seem to differ between the HW and the LW group. However, to secure that the pre-sleep conditions for the groups were homogenous, the same analyses were done separately for the two placebo groups and for the two caffeine groups. A significant difference was found on SOL on the second night between the LW and the HW group among the subjects who received placebo. In the LW group the correspondence was much higher than in the HW group, implying that worrying contributed to misperceptions of SOL. Contrary to what was concluded when comparing the total LW and HW group, this finding supports the hypothesis that worrying influences the estimation of time. An equivalent difference between the LW and the HW group among subjects who received caffeine was not found. One possible explanation to this may be that in-group variance on the effects of caffeine has led to a reduction in between-group variance on SOL.

Cognitive activity

It was found that worried subjects had more nighttime thoughts than non-worried subjects, and it was also found that worried subjects subjectively reported lower sleep quality on the first night of the experiment. The findings are in line with theories of insomnia that assume that presleep cognitive hyperarousal is associated with insomnia (e.g. Lundh & Broman, 2000). Though, a subjective complaint of low sleep quality is not equal to a diagnosis of insomnia.

It has been found that the affective valence of cognition is an important mediating factor of insomnia (Morin et al., 1993). Presleep cognition about negative sleep-related content has been reported to be significantly associated with longer SOL (Van Egeren et al., 1983). Watts et al. (1994) wanted to investigate the relationship between insomnia and worry more closely, and they were interested in the content of the presleep intrusions reported by insomniacs. Their fining that worry not necessarily was a feature of insomnia led them to conclude that worry presumably not always is the cause of insomnia. Further more, no significant interaction effects between worry and insomnia were reported. This finding was supported in the present study in that there were not observed any interaction effects between worry and induced sleeplessness on either the subjective or the objective sleep parameters. Watts et al. (1994) also reported that non-worried insomniacs had more thoughts about sleep compared to non-worried non-insomniacs. This was partly supported in the present study in that induced sleeplessness led to an increase on Thoughts about sleep regardless of whether the subjects belonged to the HW or the LW group. Another finding from the study of Watts et al. (1994) was that worried subjects who were non-insomniacs showed increased levels of trivial mental activity and thoughts about work. In the present study this finding was supported in that worry was found to have a main effect all the subscales of the NTTQ. Watts et al. (1994) concluded that insomnia seems to be particularly associated with sleep-related thoughts, while worry is associated with thoughts of a more general character. The present study found support for these conclusions in that induced sleeplessness caused an increase in Thoughts about sleep. Since the HW was found to score higher than the LW group on all of the subfactors of the NTTQ on both nights, the conclusions that worry is associated with thoughts of a general character was supported. However, there are some limitations to the comparison of the two studies. In the study of Watts et al. (1994) self-defined insomniacs were used, while in the study at hand sleeplessness was induced by the distribution of caffeine. The characteristic thoughts of an insomniac could therefore not be measured, but rather thoughts that are produced when occasionally experiencing a sleeplessness night. Further, in the study of Watts et al. (1994) sleep was not manipulated and the various groups were compared against each other, while in the present study sleep was manipulated and repeated measures were used.

In a study by Wicklow and Espie (2000) the question of what kind of presleep intrusions that is active in delaying sleep was addressed. Voice-activated audiotape recordings were used to measure presleep cognitive activity, and on the basis of these recordings categories of presleep cognitive activity were made. Rehearsing, planning and problem solving formed the largest component of the presleep cognitive activity. This is in line with the finding from the present study that the Mental activity and rehearsal increased as a function of induced sleeplessness. However, Wicklow and Espie (2000) stated that it could not be concluded that the thoughts were worrisome to the subjects, and neither that they were causal in keeping the subjects awake since it was observed that SOL correlated with amount of rehearsal and planning. Further, they found that the subjects typically reported preoccupations with being unable to fall asleep. This is in line with the finding from the present study that induced sleeplessness had a main effect on the item of the NTTQ concerning thoughts about being unable to fall asleep. A conclusion from their study was that even though a specific type of thinking is present in the presleep state, it does not mean that it is causal in keeping a person awake. It seems reasonable to draw the same conclusion from this study, as illustrated in the finding that presleep activity seems to be an epiphenomenon of induced sleeplessness. However, the trend that induced sleeplessness interacted with worry on Thoughts about sleep indicates that when worried people experience sleeplessness they may produce thoughts about sleep, which again may contribute to the maintenance of the sleeplessness. The trend implicates that the relationship between thinking about sleep and SOL might be of a transactional character. If that is the case, it appears like a good example of when a solution becomes a problem considering that the subjects presumably believes that thinking about sleep will eventually put them sleep. However, the trend was not significant, and would have to be replicated for further discussion.

In the present study it was found that the subjects who received caffeine experienced a general increase in the total sum of NTTQ from the first to the second night, and that this increase did not differ between the HW and the LW group. When looking on the separate items of the NTTQ, it appears that the increase in nighttime thoughts due to induced sleeplessness not generally occurred in typical worry domains, as the cognitive activity that it caused was not typically negative. The thoughts that increased concerned trivial things, unimportant things, wanting to sleep, not being able to sleep, important things, and long-term plans or projects. However, even thought the content of these thoughts do not appear to have a worrisome quality to them, it is possible that the subjective experience of having the thought may have differed between subjects and that some experienced them as worrisome and others did not. Considering that the emotional charge of worrying is placed within the perceived basis in reality factor (Langlois et al., 2000), it becomes relevant to speculate in witch degree the thoughts that increased due to induced sleeplessness were perceived by the subjects to be realistic.

A question that arises is whether the thoughts that increased should be labeled as rumination rather than worrying. As mentioned previously, worrying can be considered a subtype of ruminative thought which is negative, future-oriented, and that can have both a discrepancy focus and an attainment focus (Martin & Tesser, 1996). Other types of negative rumination are *working trough* and *regret.* Both are oriented in the past but working trough has a discrepancy focus while regret has an attainment focus. *Current concerns* is negative, oriented in the present, and can both have a discrepancy focus and an attainment focus. Types of positive rumination that is oriented in the past are *downward counterfactual* which has discrepancy focus, and *reminiscing* which has an attainment focus. Types of positive rumination that is oriented in the present are *flow* which has a discrepancy focus, and *basking* which has an attainment focus. Finally types of positive rumination that is oriented in the future are *optimism* which has a discrepancy focus, and *anticipation* which has an attainment focus.

Using this categorization of ruminative thoughts as a starting point for the labeling of the cognitive activity that arose as a consequence of induced sleeplessness in the present study, it is relevant to look at the content of each of the items of the NTTQ that increased. The thoughts that concerned trivial things I don't have to think about (item 2), can hardly be described as negative in that they concerned trivial things, and they can therefore not be categorized as worrying. The placement in past, present, or future, and the focus of the thought is difficult to define. Rehearsing unimportant things I will do tomorrow (item 3) is a future-oriented thought. Though, *unimportant* does not make it positive and therefore it cannot be optimism or anticipation. The negative quality of it is not obvious, but it may be considered worrisome since the person has the need to rehearse about it. Wanting to sleep (item 5) seems to have a focus in the present and has a negative quality to it in that it represents a goal that is not attained, and therefore it can be thought about as a current concern. Not being able to sleep (item 7) involves a negative expectation about the near future and can therefore be thought about as worrisome. Important things (item 13) is difficult to categorize either as negative or positive, and it seems likely that it has a temporal focus either in the present or in the future. Whether it has an attainment focus or discrepancy focus is not possible to decide. Consequently it is possible that worrying is measured on this item, but it is not certain. Long-term plans or projects (item 14) is future oriented and has a positive undertone. It seems likely that the thoughts measured on this time have a discrepancy focus, and it can consequently be placed in the category of optimism. Summing up, two of the items (item 3 and 7) can be put in the worry category when using the categorization system suggested by Martin and Tesser (1996), and it is possible that one other item also can be put in the worry category (item 13). Three items would most likely not fall into the worry category (item 2, item 5, and item 14). By looking closer on the items of the NTTQ that increased then, it turns out that it would be more accurate to describe them as ruminative than as worrisome, because of the lack of negative valence on a number of the items.

An implication from this line of reasoning is that the development of instruments that can discriminate between subtypes of rumination, like for example worrying and working through, is needed. Some measures for presleep cognition do exist though. The presleep arousal scale is a self-report measure of the presleep state (Nicassio et al., 1985). It consists of a cognitive and a somatic subscale which have been found to correlate with depression, anxiety, and sleeping difficulty. The items on the cognitive subscale are similar to some of the items on the NTTQ (e.g., *worry about falling asleep, review or ponder events of the day, being mentally alert,* and *can't shot off your thoughts*). Like the NTTQ, the questionnaire measures the cognitive activity, but it does not measure different modes of thinking, like for example worrying or other types of rumination. Espie and Harvey (2002) are currently working on an inventory that measures presleep intrusive thoughts. The questionnaire has been reported to be a valid and reliable instrument that successfully discriminates between insomniacs and good sleepers (Espie & Harvey, 2002).

The discussion of whether the cognitive activity that increased due to the manipulation should be described as worrying or rumination can be further highlighted from the findings that two of the subfactors of the SMRI, the Distraction factor and the Emotionality factor, correlated positively with the PSWQ, while one of them, the Motivation factor, correlated negatively with the PSWQ. Scott and McIntosh (1999) reported similar findings from a study of the validly of the SMRI. Taken together these findings suggest that worry has similar characteristics to the general concept of rumination, and also that it has a distinct characteristic that is not shared by all the subgroups of the general concept, which makes it a subgroup of rumination. This is in line with the above reasoning. Rumination does not have to be negative and worrisome, and people who ruminate about how to reach their goals do not necessarily score high on a measure of worry.

The possibility that cognitive dysfunction in terms of dysfunctional beliefs about sleep is a causal factor of sleeplessness, was not addressed directly in the present study as it was not used specific measures for this type of thoughts. However, two of the items on Thoughts about sleep could possibly be considered a dysfunctional belief according to Morin's (1993) outline of the concept. Item 7 (not being able to sleep) may indirectly involve unrealistic sleep expectation, and item 8 (being tired tomorrow) may involve misattribution or amplification of the consequences of sleep loss. However, the general conclusion from the study was that nighttime thoughts appear to occur as an epiphenomenon of sleeplessness, and therefore it can not be concluded that thoughts of a specific type were causal in keeping subjects awake.

It has been reported that type of presleep cognitions is related to the estimation of SOL, as illustrated in a finding by Van Egeren et al., (1985). They reported that presleep cognitions concerning negative sleep related content (e.g., thoughts about not falling asleep) were significantly associated with longer reported SOL in the laboratory and greater general concerns about having a sleep problem. The authors concluded that the finding was a tentative support for a cognitive theory of subjective insomnia. In line with the finding form their study it was hypothesized in the present study that there would be a larger discrepancy between the objective and the subjective sleep parameters in the HW group than in the LW group. This was supported on the second night only in the placebo, and not the caffeine, group. It is possible that when the participants in the caffeine group experienced the physiological arousal from the caffeine they knew what to attribute the arousal to, and therefore the subjective complaint of poor sleep did not increase. This interpretation is in line with an observation that insomnia subjects who received placebo and who were told that the pills would cause arousal, fell asleep more quickly than they had done on nights without pills (Storms & Nisbett, 1970). The authors concluded that this happened because the subjects attributed their arousal to the pills rather than to their emotions.

Other disorders

When considering what kind of cognitive activity that is present in insomnia, it becomes relevant to differentiate it from cognitive activity that is central in other disorders, if possible. In order to make a diagnosis of primary insomnia this differentiating seems essential to make. To distinguish worrying from obsessive thinking for example, it might become relevant to ask the subjects whether they experience their thinking as egosyntonic and realistic, which would be an indication of worrying, or whether they experience it as egodystonic and not based in reality, which would be an indication of obsessive thinking (Langlois et al., 2000). When considering that depression may be present, it becomes relevant to address in which degree the thoughts can be categorized as negative automatic thinking (Beck, 1970), rather than worrying. These distinctions are instrumental to make when considering differential diagnosis, etiology, and treatment. Further, it is possible that people have individual ways of reacting to sleeplessness that is representative of their characteristic repertoire of handling problems. This reasoning is in line with Morin's (1993) integrative model of insomnia.

Models of insomnia

Morin's integrative model. The findings that worried subjects in general had more nighttime thoughts than non-worried subjects is compatible with Morin's (1993) model stating that hyperarousal is a mediating factor of insomnia. However, the relationship between worrying and nighttime hyperarousal is not equivalent to a relationship between nighttime hyperarousal and insomnia. Morin's integrative model implies that worrying can be seen as emotional arousal in that it involves thinking that has a negative affective valence. The hypothesis that worried subjects have a lower sleep quality (as measured by sleep efficiency, SOL and WASO) than non-worried subjects, was supported according to the sleep diary on the first night of the experiment, but not according to the actigraph. On the second night, the caffeine manipulation had significant effects on several sleep parameters according to both the sleep diary and the actigraph. These findings are in line with Morin's model in that physiological arousal was found to be a predisposing factor for lower quality sleep. Secondly, the model was supported in that induced sleeplessness (physiological arousal) led to an increase in the total amount of nighttime thoughts. Further there was observed an increase on Thoughts about sleep. This is in line with the assumption that sleeplessness can cause an increase in worries about sleep loss. The non-significant trend of an interaction effect between worry and induced sleeplessness on Thoughts about sleep that was reported suggests that a transactional relationship between thoughts about sleep and sleeplessness may exist in people who are worried. The trend may become significant if the study is replicated with a higher power.

Espie's psychobiological model. The findings are also compatible with Espie's (2002) model of sleep in that both affective arousal (worry) and autonomic arousal (caffeine) were associated with sleeplessness. The hypothesis that worry would be associated with sleeplessness was only supported according to the sleep diary, and not according to the actigraph. However, following the model, one possible explanation for this may be that the meditating factor for the complaint of insomnia is hypothesized to be either affective or cognitive. Having this as a starting point, it would be expected that a complaint of insomnias would be registered in a subjective measure of sleep first since a subjective measure is tapping cognitive and affective factors of the sleep experience. As a matter of fact, Espie's (2002) model is implicitly pointing to the distinction between subjective and objective insomnia. In the present study, it was observed a relationship between worry and lower sleep quality only according to the sleep dairy, and not according to the actigraph. This could be interpreted as support for the conclusion that worrying is associated with the subjective evaluation of sleep quality (e.g., Van Egeren et al., 1985).

Lundh and Broman's model of sleep-interfering and sleep-interpreting processes. The finding that worry was associated with lower sleep quality on the first night of the experiment according to the sleep diary can be interpreted as a support for the hypothesis from Lundh and Bromans's (2000) model that cognitive strategies and arousability factors are vulnerability factors for sleep-interpreting processes. The observation that induced sleeplessness caused an increase on Thoughts about sleep, supported the hypothesis that arousal may produce more negative interpretations of sleep and sleeplessness. There was not found support for a bi-directional relationship between sleep-interpreting and sleep-interfering processes. However, the trend of an interaction between worry and induced sleeplessness on Thoughts about sleep indicates that this relationship possibly exists.

Limitations of the study

An obvious weakness of the experiment was that it only lasted for two days. This may have been a too short sampling period to test whether people who are worried would worry relatively more than non-worried people when experiencing sleeplessness. Two days of data sampling does not allow for testing the assumption that when sleeplessness adds up night after night, people who are already worried worry relatively more than people who are not initially worried, as a consequence of the sleeplessness,

Secondly, the NTTQ is primarily a measure of thoughts, and not worries. In other words, the scores on the NTTQ are not equivalent to a measure of worry. However, many of the factors that are included on the questionnaire are explicitly labeled as worries, and others have a worrisome quality to them. (See Appendix.)

The above-mentioned considerations challenge the internal validity of the experiment. However, the consistency of the effect of induced sleeplessness on almost all sleep parameters and on the NTTQ reinforces the validity of the study.

The external validity of the study is challenged by the sample that was used. As the sample on average consisted of young female undergraduate students, further investigation is needed to see if the results can be generalized to other populations. It is possible that inducing sleeplessness in various clinical populations would cause different patterns of cognitive activity depending on the general problems the subjects are faced with in their lives. Insomniacs may have a characteristic way of responding to sleeplessness that is not represented in non-insomniacs.

Another challenge to the external validity of the study is that the participants were not screened for psychological problems that are related to worry or insomnia. Considering that worry is a core symptom of GAD and that insomnia is a symptom of depression (DSM-IV, 1994), it is reasonable to assume that the presence of these conditions would complicate the interpretation of the findings.

It is important to note that induced sleeplessness is not equivalent to insomnia regardless of the finding that caffeine was found to be effective in inducing sleeplessness. Further, induced sleeplessness was not found to have a differential affect on the LW and the HW group. This was interpreted as a lack of support for the hypothesis that an interaction of worrying and sleeplessness causes a person to stay awake. It may be though that the artificial disturbance of sleep reduced the worrying that would otherwise have been present and therefore an interaction effect between worrying and sleeplessness was not found.

At last, worry is not a measure of insomnia. The finding that worry is related to the score on the NTTQ is therefore only an indirect support for a relationship between worry and insomnia in that a score on the NTTQ is associated with cognitive hyperarousal, which again is assumed to counteract sleep. However, it was observed a relationship between subjective measures of sleep and worry.

The design allows for addressing the causal relationship between worrying and induced sleeplessness. However, considering that induced sleeplessness is not equivalent to sleeplessness that occurs from time to time or on a more regular basis, it is less certain whether the design addresses "naturally" occurring sleeplessness. The conclusion that cognitive activity appears to be an epiphenomenon of wakefulness must be interpreted within this framework.

Conclusions and future research

Caffeine was effective in inducing sleeplessness, as measured by an increase in SOL, and in lowering sleep quality in general. Worried subjects had in general more nighttime thoughts. The amount of nighttime thoughts increased as a consequence of induced sleeplessness. This finding supports the idea of nocturnal cognitive activity being an epiphenomenon of wakefulness. Of the thoughts that increased due to induced sleeplessness, only half of them could be described as worrisome. A better description of the cognitive activity that increased would be rumination, under which worrying can be considered a subgroup. If this finding is recurrent, it can be of clinical importance. There was a non-significant trend of an interaction effect between worry and induced sleeplessness on Thoughts about sleep, indicating that initial sleeplessness in combination with worry may cause thoughts about sleep, which again may contribute to the maintenance of sleeplessness. Findings from the study also partly supports the hypothesis that worrying is a mediator of the subjective complaint of insomnia.

Future research is needed to investigate if different clinical populations react differently to sleeplessness. A focus should be put on the subjective experience of the cognitive activity so that distinctions can be made between obsessions, dysfunctional beliefs, subtypes of rumination, and negative automatic thoughts. To make these fine-grained distinctions, there is a need to develop questionnaires that can capture the subjective experience of having a specific thought. More research on the causal relationship between cognitive activity and sleeplessness is needed.

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Table 1

Group differences on PSWQ and SMRI

	Low Worry (n = 49)	High Worry (n = 47)	Mean difference $t(df)$
Mean PSWQ	34.4	62.0	-24.93(94)***
Mean SMRI - Total	37.0	43.9	-6.19(94)***
Mean SMRI - Emotionality	8.7	14.0	-7.69(94)***
Mean SMRI - Distractibility	13.4	16.9	-4.96(94)***
Mean SMRI - Motivation	13.0	15.0	2.83(94)**

** $p < .01$, two-tailed; *** $p < .001$, two-tailed.

Table 2

Correlations between the sum score of the PSWQ and the SMRI

n = 96	*r*
PSWQ and SMRI - total	0.54***
PSWQ and SMRI - emotionality	0.65***
PSWQ and SMRI - distractibility	0.47***
PSWQ and SMRI - motivation	-0.33***

*** $p < .001$, two-tailed.

Table 3

Mean scores across groups on the NTTQ, and on the sleep parameters from the sleep dairy and the actigraph

	LW, Placebo *n* = 23 - 26	LW, Caffeine *n* = 20 - 23	HW, Placebo *n* = 21 - 23	HW, Caffeine *n* = 22 - 24
NTTQ, 2. night, Total	35.1	42.1	46.9	56.3
NTTQ, 2. night, Thoughts about sleep	7.3	9.3	8.2	13.0
NTTQ, 2. night, Work and recent concerns	3.8	4.5	4.9	6.0
NTTQ, 2. night, Somatic preoccupations	5.2	6.4	6.1	8.1
NTTQ, 2. night, Mental activity and rehearsal	7.5	9.3	9.5	11.8
NTTQ, 2. night, Positive concerns and plans	6.2	7.1	8.3	8.4
NTTQ, 2. night, Family and long-term concerns	5.7	6.7	9.7	9.6
NTTQ, difference from 1. - 2. night, Total	-1.2	-6.2	3.5	-5.1
NTTQ, difference from 1. - 2. night, Thoughts about sleep	-1.2	-2.7	1.3	-3.0
NTTQ, difference from 1. - 2. night, Work and recent concerns	-0.1	-0.4	0.7	0.1
NTTQ, difference from 1. - 2. night, Somatic preoccupation	-1.0	-1.3	0.1	-1.4
NTTQ, difference from 1. - 2. night, Mental activity and rehearsal	0.1	-1.0	0.0	-1.4
NTTQ, difference from 1. - 2. night, Positive concerns and plans	0.6	-1.0	1.2	-0.7

	LW, Placebo *n* = 23 - 26	LW, Caffeine *n* = 20 - 23	HW, Placebo *n* = 21 - 23	HW, Caffeine *n* = 22 - 24
NTTQ, difference from 1. - 2. night, Family and long-term plans	-0.2	-1.0	0.4	0.6
Sleep diary, 2. night, sleep efficiency	87.8	75.1	85.0	73.0
Sleep diary, 2 night, SOL	28.3	78.5	27.2	88.0
Sleep diary, 2. night, WASO	17.9	28.5	23.0	29.3
Actigraph, 2. night, sleep efficiency	87.7	83.2	90.4	82.1
Actigraph, 2 night, SOL	15.0	19.7	7.5	24.9
Actigraph, 2. night, WASO	48.3	73.1	45.6	67.4
Sleep diary, difference from 1. - 2. night, sleep efficiency	1.6	14.9	-2.3	12.1
Sleep diary, difference from 1. - 2. night, SOL	-4.3	-54.9	10.7	-46.4
Sleep diary, difference from 1. - 2. night, WASO	-6.5	-15.9	1.2	-11.7
Actigraph, difference from 1. - 2. night; sleep efficiency	0.7	6.6	-0.4	4.7
Actigraph, difference from 1. - 2. night, SOL	3.8	-4.4	4.0	0.2
Actigraph, difference from 1. - 2. night, WASO	-2.0	-32.0	-3.2	-23.7

Note. The negative values on the NTTQ difference variables (1. night– 2. night) represent an increase in score from the first night to the second night, while positive values represent a decrease. The same is true for the SOL and WASO difference variables. For sleep efficiency, a positive value on the difference variable represents a decrease in sleep efficiency, while a negative value represents an increase.

Table 4

Main effects and interaction effects of worry and induced sleeplessness on NTTQ, and on sleep efficiency, SOL, and WASO according to the actigraph and the sleep diary

	F values (*df* group/*df N*)		
	Worry	Induced sleeplessness	Worry X Induced sleeplessness
NTTQ, 2. night, Total	25.52, (1,94)***	10.25, (1,94)**	0.21, (1,94)
NTTQ, 2. night, Thoughts about sleep	8.24, (1,94)**	18.33, (1,94)***	3.02, (1,94)
NTTQ, 2. night, Work and recent concerns	11.34, (1,94)***	5.00, (1,94)*	0.24, (1,94)
NTTQ, 2. night, Somatic preoccupations	5.15, (1,94)*	8.30, (1,94)**	0.40, (1,94)
NTTQ, 2. night, Mental activity and rehearsal	10.10, (1,94)**	8.24, (1,94)**	0.10, (1,94)
NTTQ, 2. night, Positive concerns and plans	9.02, (1,94)**	0.65, (1,94)	0.47, (1,94)
NTTQ, 2. night, Family and long-term concerns	29.75, (1,94)***	0.55, (1,94)	0.69, (1,94)
NTTQ, difference from 1. - 2. night, Total	2.56, (1,93)	14.54, (1,93)***	1.04, (1,93)
NTTQ, difference from 1. - 2. night, Thoughts about sleep	1.92, (1,94)	13.74, (1,94)***	3.16, (1,94)
NTTQ, difference from 1. - 2. night, Work and recent concerns	3.02, (1,94)	1.44, (1,94)	0.11, (1,94)
NTTQ, difference from 1. - 2. night, Somatic preoccupations	0.92, (1,94)	2.90, (1,94)	1.01, (1,94)
NTTQ, difference from 1. - 2. night, Mental activity and rehearsal	0.16, (1.93)*	5.03, (1,93)*	0.12, (1,93)
NTTQ, difference from 1. - 2. night, Positive concerns and plans	1.37, (1,94)	17.90, (1,94)***	0.16, (1,94)
NTTQ, difference from 1. - 2. night, Family and long-term concerns	4.36, (1.94)*	0.40, (1,94)	0.32, (1,94)

	F values (df group/df N)		
	Worry	Induced sleeplessness	Worry X Induced sleeplessness
Sleep Diary, 2. Night, sleep efficiency	0.77, (1,92)	19.90, (1,92)**	0.02, (1,92)
Sleep Diary, 2. Night, SOL	0.15, (1,94)	25.22, (1,94)***	0.23, (1,94)
Sleep diary, 2. night, WASO	0.21, (1,92)	1.69, (1,92)	0.11, (1,92)
Actigraph, 2. night; sleep efficiency	0.17, (1,84)	10.35, (1,84)**	0.97, (1,84)
Actigraph, 2 night, SOL	0.02, (1,84)	2.12, (1,84)	0.70, (1,84)
Actigraph, 2. night, WASO	0.19, (1,84)	5.72, (1,84)*	0.02, (1,84)
Sleep diary, difference from 1. - 2. night, sleep efficiency	1.66, (1,92)	29.08, (1,92)***	0.05, (1,92)
Sleep diary, difference from 1. - 2. night, SOL	1.14, (1,94)	23.78, (1,94)***	0.09, (1.94)
Sleep diary, difference from 1. - 2. night, WASO	0.85 (1,92)	3.03, (1,92)	0.07, (1.92)
Actigraph, difference from 1. - 2. night, sleep efficiency	0.68, (1,84)	8.80, (1,84)**	0.05, (1,84)
Actigraph, difference from 1. - 2. night, SOL	0.07, (1,84)	0.49, (1,84)	0.07, (1.84)
Actigraph, difference from 1. - 2. night, WASO	0.15, (1,84)	7.69, (1,84)**	0.27, (1.84)

* $p < .05$, two-tailed; ** $p < .01$, two-tailed; *** $p < .001$, two-tailed.

Table 5

Correlation between the sleep diary and the actigraph on sleep efficiency, SOL, and WASO, and z-scores for the difference in correlation between the LW placebo and the HW placebo group, and between the LW caffeine and HW caffeine group.

	Placebo			Caffeine		
	LW *n* = 23 *r*	HW *n* = 21 *r*	*z*-score for difference in correlation	LW *n* = 19-20 *r*	HW *n* = 21 - 22 *r*	*z*-score for difference in correlation
2. night, sleep efficiency	0.20	-0.01	0.65	0.55*	0.45*	0.39
2. night, SOL	0.68**	0.07	2.34*	0.54*	0.32	0.82
2. night, WASO	0.06	-0.03	0.28	0.12	0.44*	1.02

* $p < .05$, two-tailed; ** $p < .01$, two-tailed.

Table 6

Mean scores across groups on the difference scores of the separate items of the NTTQ

	LW, Placebo *n* = 26	LW, Caffeine *n* = 23	HW, Placebo *n* = 22 - 23	HW, Caffeine *n* = 24
NTTQ, difference from 1. - 2. night, item 1	-0.1	-0.2	-0.2	-0.3
NTTQ, difference from 1. - 2. night, item 2	-0.2	-0.4	0.3	-0.4
NTTQ, difference from 1. - 2. night, item 3	0.1	-0.5	-0.1	-0.5
NTTQ, difference from 1. - 2. night, item 4	0.2	0.1	0.0	-0.1
NTTQ, difference from 1. - 2. night, item 5	-0.2	-0.9	0.3	-0.9
NTTQ, difference from 1. - 2. night, item 6	0.1	0.1	0.3	-0.4
NTTQ, difference from 1. - 2. night, item 7	-0.3	-1.1	0.4	-1.1
NTTQ, difference from 1. - 2. night, item 8	-0.7	-0.7	0.3	-0.5
NTTQ, difference from 1. - 2. night, item 9	-0.1	0.1	-0.5	0.2
NTTQ, difference from 1. - 2. night, item 10	-0.1	-0.1	0.4	0.5
NTTQ, difference from 1. - 2. night, item 11	-0.1	-0.6	0.2	0.0
NTTQ, difference from 1. - 2. night, item 12	0.1	-0.3	0.3	-0.1
NTTQ, difference from 1. - 2. night, item 13	0.2	-0.7	0.3	-0.3

	LW, Placebo *n* = 26	LW, Caffeine *n* = 23	HW, Placebo *n* = 22 - 23	HW, Caffeine *n* = 23 - 24
NTTQ, difference from 1. - 2. night, item 14	0.2	-0.2	0.6	-0.1
NTTQ, difference from 1. - 2. night, item 15	0.2	-0.1	0.3	-0.3
NTTQ, difference from 1. - 2. night, item 16	-0.2	-0.1	-0.3	-0.5
NTTQ, difference from 1. - 2. night, item 17	-0.2	-0.3	-0.2	-0.4
NTTQ, difference from 1. - 2. night, item 18	0.1	0.3	0.5	0.2
NTTQ, difference from 1. - 2. night, item 19	-0.2	-0.1	0.1	-0.0
NTTQ, difference from 1. - 2. night, item 20	0.1	-0.4	0.5	0.1

Note. The negative values on the NTTQ difference variables (1. night – 2. night) represent an increase in score from the first night to the second night, while positive values represent a decrease.

Table 7

Main effects and interaction effects of worry and induced sleeplessness on the repeated measures of the separate items of the NTTQ

	F values (*df* group/*df N*)		
	Worry	Induced sleeplessness	Worry X Induced sleeplessness
NTTQ, item 1	0.38, (1,93)	0.33, (1,93)	0.02, (1,93)
NTTQ, item 2	1.11, (1,93)	5.67, (1,93)*	1.21, (1,93)
NTTQ, item 3	0.48, (1,93)	7.15, (1,93)**	0.13, (1,93)
NTTQ, item 4	0.85, (1,93)	0.35, (1,93)	0.01, (1,93)
NTTQ, item 5	0.71, (1,94)	11.31, (1,94)***	0.61, (1,94)
NTTQ, item 6	0.26, (1,94)	2.46, (1,94)	2.06, (1,94)
NTTQ, item 7	1.81, (1,94)	17.15, (1,94)***	1.38, (1,94)
NTTQ, item 8	4.65, (1,94)*	2.16, (1,94)	3.08, (1,94)
NTTQ, item 9	0.52, (1,94)	3.23, (1,94)	2.01, (1,94)
NTTQ, item 10	7.94, (1,94)**	0.01, (1,94)	0.07, (1,94)
NTTQ, item 11	3.04, (1,94)	1.68, (1,94)	0.20, (1,94)
NTTQ, item 12	0.89, (1,94)	2.87, (1,94)	0.01, (1,94)
NTTQ, item 13	0.72, (1,94)	8.31, (1,94)**	0.53, (1,94)
NTTQ, item 14	1.54, (1,94)	6.54, (1,94)*	0.82, (1,94)

	F values (*df* group/*df* *N*)		
	Worry	Induced sleeplessness	Worry X Induced sleeplessness
NTTQ, item 15	0.01, (1,94)	3.08, (1,94)	0.41, (1,94)
NTTQ, item 16	0.82, (1,94)	0.10, (1,94)	0.59, (1,94)
NTTQ, item 17	0.16, (1,94)	0.35, (1,94)	0.08, (1,94)
NTTQ, item 18	0.56, (1,94)	0.03, (1,94)	0.87, (1,94)
NTTQ, item 19	0.58, (1,94)	0.03, (1,94)	0.56, (1,94)
NTTQ, item 20	3.18, (1,94)	2.18, (1,94)	0.01, (1,94)

$p < .05$, two-tailed; ** $p < .01$, two-tailed; *** $p < .001$, two-tailed.

Appendix

NIGHT-TIME THOUGHTS QUESTIONNAIRE

Instruction: Circle the number that best describes how much you thought about the following last night.

	not at all				**a lot**
1. Unimportant things	1	2	3	4	5
2. Trivial things I don't need to think about	1	2	3	4	5
3. Rehearsing unimportant things I will do tomorrow	1	2	3	4	5
4. Rehearsing important things I will do tomorrow	1	2	3	4	5
5. Wanting to sleep	1	2	3	4	5
6. Noise or other distractions	1	2	3	4	5
7. Not being able to sleep	1	2	3	4	5
8. Being tired tomorrow	1	2	3	4	5
9. Things that happened a long time ago	1	2	3	4	5
10. Concerns about family	1	2	3	4	5
11. Going over and over the same thing	1	2	3	4	5
12. Things I am worried about	1	2	3	4	5
13. Important things	1	2	3	4	5
14. Long-term plans or projects	1	2	3	4	5
15. Things I enjoy	1	2	3	4	5
16. Relaxing my body	1	2	3	4	5
17. Feeling tense	1	2	3	4	5
18. Feeling too hot or too cold	1	2	3	4	5
19. Concerns about work	1	2	3	4	5
20. Things that happened yesterday	1	2	3	4	5